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Meta-Analyses of the Associations of Respiratory Health Effects with Dampness and Mold in Homes

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ABSTRACT

The Institute of Medicine (IOM) of the National Academy of Sciences recently completed a critical review of the scientific literature pertaining to the association of indoor dampness and mold contamination with adverse health effects. In this paper, we report the results of quantitative meta-analyses of the studies reviewed in the IOM report plus other related studies. We developed point estimates and confidence intervals (CIs) of odds ratios (ORs) that summarize the association of several respiratory and asthma-related health outcomes with the presence of dampness and mold in homes. The ORs and CIs from the original studies were transformed to the log scale and random effect models were applied to the log ORs and their variance. Models accounted for the correlation between multiple results *within* the studies analyzed. Central estimates of ORs for the health outcomes ranged from 1.34 to 1.75. CIs (95%) excluded unity in nine of ten instances, and in most cases the lower bound of the CI exceeded 1.2. Based on the results of the meta-analyses, building dampness and mold are associated with approximately 30% to 50% increases in a variety of respiratory and asthma-related health outcomes.

Keywords: asthma, dampness, health, meta-analysis, mold

PRACTICAL IMPLICATIONS

The results of these meta-analyses reinforce the IOM's recommendation that actions be taken to prevent and reduce building dampness problems, and also allow estimation of the magnitude of adverse public health impacts associated with failure to do so.

INTRODUCTION

The association of adverse health effects with dampness and mold in buildings has been the subject of much research. Most studies on this topic have found an increased risk of one or more adverse health effects in buildings with signs of dampness or visible mold. The Institute of Medicine (IOM) of the National Academy of Sciences recently completed a critical review (IOM 2004) of this scientific literature. The IOM concluded that *excessive indoor dampness is a public health problem*, noted that dampness problems are common, and recommended corrective measures. While the IOM report summarized the main features and results of the reviewed studies, which included a broad range of health outcomes, it provided no quantitative summaries of the findings of these studies.

In this paper, we report the results of quantitative meta-analyses of the studies reviewed in the IOM report and other similar studies that met specified study inclusion criteria. A meta-analysis

uses statistical methods to combine data from different but comparable research studies, in order to provide a quantitative summary estimate on the size and variability of an association. Studies are generally selected for relevance, quality, and similarity. The contribution of larger, more precise studies to the summary estimate is generally more heavily weighted. Results of meta-analyses presented here are central point estimates and confidence intervals (CIs) of odds ratios (ORs) that summarize the magnitude of increased risk of several health outcomes in buildings with dampness and mold. The central estimates and CIs of ORs, if assumed to reflect causal relationships, can be used to communicate the importance of dampness and mold as health risks, to estimate the economic significance of dampness- and mold-related health effects to society, and to estimate the magnitude of health and economic benefits from programs that reduce dampness and mold.

METHODS

We began with the full list of studies included in Tables 5-1, 5-2, 5-3, 5-6, 5-7, and 5-8 of the recent IOM review (IOM 2004) and added studies identified in a search using PubMed. Search terms included combinations of dampness, building, home, health, asthma, respiratory, symptoms, and similar terms. Additional studies were identified via the reference lists of the original set of papers. Papers meeting the following criteria were selected for use in the meta-analyses:

- 1) Article was published in a refereed archival journal.
- 2) Article was based on original data; i.e., not a review article or meta-analysis.
- 3) Data were analyzed statistically to produce an odds ratio or relative risk (RR) and confidence interval (CI).
- 4) Risk factors included one or more measures of dampness, mold, or dampness and mold in housing located in a developed country setting.
- 5) Health outcomes were one or more of the outcomes included in this analysis (see below).
- 6) Study controlled for potential confounding by the following factors via study design or analysis method: age, gender, smoking in home or prenatal smoking; and some measure of socioeconomic status (SES). No control for SES was required if the study subjects were from Sweden which has limited SES variation and where control for SES in studies is not common.
- 7) For analyses with asthma development as the outcome, a subject age three years or greater was required.
8. Study included more than two damp and two non-damp buildings or assessed spatial variability of dampness within buildings.

Ideally, each meta-analysis would combine estimates only from studies with the same precisely defined health outcome, risk factor, and population/subjects. Because the original studies included many differently defined respiratory health outcomes, risk factors, and populations, this was not possible, and we analyzed groups of studies that were as similar as practicable with respect to these. Table 1 shows the categories of health outcome used in meta-analyses here, with the specific outcomes from reviewed studies included in each category.

Table 1. Health outcomes from reviewed studies, grouped into outcome categories used in meta-analyses

Category in Meta-Analysis	Outcomes from Individual Studies Included in Each Category
Upper respiratory tract symptoms	irritated, stuffy, or runny nose; nasal symptoms; nasal congestion; nasal congestion or runny nose; nasal excretion; nose irritation; rhinitis; sinusitis; allergic rhinitis; allergy; hay fever
Cough	cough; cough with phlegm; cough without phlegm; day or night cough; dry cough; morning cough; long-term cough; chronic cough; cough on most days for 3 months; night cough with wheeze; persistent cough; nocturnal cough; cough 3 months of year apart from colds
Wheeze	wheeze; persistent wheeze; wheeze apart from cold; wheeze including shortness of breath and asthma; wheeze/breathlessness; wheezing or whistling in the chest; wheeze in last year; wheeze apart from colds on most days; wheeze after exercise
Ever diagnosed with asthma	<ul style="list-style-type: none"> • positive response to -- has a doctor ever diagnosed mother (father) to have attacks of shortness of breath (asthma)¹; • positive response to-- did a doctor ever diagnose your having attacks of shortness of breath or asthma?; • physician-diagnosed asthma; • physician-diagnosed asthma, ever (atopic and non-atopic); • physician diagnosis of asthma since age > 16; • self-reported physician-diagnosed or nurse-diagnosed asthma
Current asthma	<ul style="list-style-type: none"> • current physician-diagnosed asthma, defined as diagnosis plus symptoms in last 12 months; • ever doctor-diagnosed asthma, plus asthma symptoms or medication in past 12 months; • current asthma defined as combination of bronchial hyper-responsiveness and at least one of wheeze or breathlessness in last 12 months; • subjective symptoms of asthma plus one or more of the following: doctor-diagnosed asthma attack and the disappearance of wheezing; doctor diagnosed asthma attack and > 15% decrease in PEF or FEV1; > 15% decrease in PEF or FEV1 in exercise test; > 20% daily variation in PEF at least 2 days per week in 4 weeks of tracking; > 15% rise in PEF or FEV1 in a bronchodilating test; • asthma - current and diagnosed by physician; • current asthma diagnosed by a doctor -- text implies that current refers to last 12 months; • asthma currently present and reported to be confirmed by a physician; • occurrence of doctor-diagnosed asthma in past year; • positive response to following two questions -- has your doctor ever said your child has asthma? does he or she still have asthma? • Doctor-diagnosed asthma and attendance of asthma clinic in 4-month period prior to study
Asthma development	<ul style="list-style-type: none"> • newly doctor-diagnosed cases of asthma in past 2.5 years; • physician diagnosis of asthma at age > 16; • first-time diagnosis of asthma • new doctor-diagnosed asthma between baseline study and follow-up study after six years

Subject types

The reviewed studies included diverse populations: adults, male adults, female adults, children (age < 18), and children (infants). For wheeze and cough outcomes, the largest numbers of studies were available and we performed separate analyses for adults (including studies of mixed or single gender), children (including studies of age < 18 or infants), and all ages combined. However, for other outcomes, too few studies were available to support separate meta-analyses for children and adults.

¹ The question's wording reflects the fact that the study assessed the risk of asthma in mothers and fathers of school children as a function of dampness in the home as part of a broader study focusing on children's asthma symptoms

Risk factors

In general, the risk factors in the reviewed studies included visible signs of dampness, visible mold, dampness or mold, dampness and mold, and measured concentrations of airborne mold spores or related agents of microbial origin. We included in meta-analyses only studies with reports of visible dampness and/or mold or mold odor as risk factors. A large majority of studies used these risk factors. We did not distinguish among dampness, mold, dampness or mold, and dampness and mold as risk factors. Our rationale – visible mold is always considered the result of excess dampness whether or not the dampness is reported, and excess dampness is very often accompanied by mold, although the mold may not be visible. Thus, it was not possible to make a clear distinction among these risk factors. We excluded from the meta-analyses ORs for associations of health effects with measured concentrations of microbial agents or measured or reported air humidity.

Presence of dampness and/or mold was determined in each study by either the occupants or the researchers. We did not distinguish between occupant-reported dampness and/or mold and researcher-reported dampness and/or mold. The discussion section of this paper provides further related information.

Health outcome categories

We categorized the health outcomes as upper respiratory tract (URT) symptoms, cough, wheeze, asthma diagnosis, current asthma, and asthma development. The specific outcome definitions varied among papers and are listed in Table 1. The URT symptom category included the broadest set of health outcomes, but nasal symptoms predominated. For asthma outcomes, based on review of the original papers, we developed different outcome categories than were used in the IOM report (IOM 2004). Our asthma development category included ORs from studies that assessed whether the *development* of asthma, as opposed to *presence* of asthma symptoms, was associated with prior dampness and mold; however, the associated time period for the asthma development and exposure assessment ranged widely and there were few studies in this category.

Statistical methods

These analyses used random effect models (DerSimonian & Laird, 1986) to summarize effect estimates across studies with substantial differences in risk assessment, symptom definition, subjects, and location. While fixed effect models account only for variability within each study from sampling error, random effect models are more appropriate here because they also account for variability between different studies. Some of the studies reported more than one estimated odds ratio, for different but related risk factors (e.g., visible mold; visible mold and dampness), or health outcome metrics (e.g., cough; night cough). Because these findings within the same study may not be statistically independent, a meta-analysis that ignored this possible dependence between multiple estimates within a study might overestimate the precision of the summary estimates. Therefore, random effect models adjusting for this type of within-study correlation were used in primary analyses. Results from analyses ignoring such correlation (not provided) differed only slightly to moderately from results of the primary analyses. We used the SAS procedure PROC MIXED, which allows fixing the within-study variances (matrix R in SAS) while estimating between-study variance (matrix G in SAS).

ORs and 95% CIs reported in each reviewed study were first transformed to the log scale. The transformed results for each outcome category were then combined using a random effect model. The model accounting for the correlation between multiple results *within* studies (“dependent sub-studies”) was

$$y_{ij} \sim N(\beta_0 + \beta_{0i}, \sigma_{ij}^2) \quad (1)$$

where:

y_{ij} is the \ln OR in the j th sub-study of the i th study;

β_0 is the fixed effect across all studies;

β_{0i} is the random effect in the i th study. $\beta_{0i} \sim N(0, \sigma^{*2})$, where:

σ^{*2} is the between-study variance; and

σ_{ij}^2 is the within-study variance, calculated from the log CI.

Estimation of percentage increases in health outcomes

To communicate the results of the meta-analyses in familiar terms, percentage increases in health outcomes were estimated from the central estimates of ORs and assumed typical outcome prevalence rates. The protocol follows.

The definition of *OR* is

$$OR = (P_1/(1-P_1))/(P_2/(1-P_2)) \quad (2)$$

where P_1 and P_2 are the prevalence rates of the health outcomes in the populations with and without the risk factor, e.g., mold, respectively. When P_1 and P_2 are much smaller than unity, which is the typical case for this paper, the *OR* is approximately equal to P_1 divided by P_2 and the percentage increase in the outcome in the population with the risk factor, denoted by I , is then approximated as follows

$$I \sim 100\% (OR - 1) \quad (3)$$

In the more general case

$$I = 100\%((P_1 - P_2)/P_2) \quad (4)$$

Initial estimates of I were developed using equation 3. To derive more accurate (slightly smaller) estimates of I , values of P_2 were calculated from equation 2 with assumed typical values of P_1 and our central estimates of *OR*. I was then calculated with equation 4. We assumed a 12% prevalence rate for asthma outcomes and a 25% prevalence rate for URT and cough symptoms.

RESULTS

Overall, 33 studies were selected for inclusion in these meta-analyses. Details on the included studies are provided in Appendix 1. Major results for the specific meta-analyses, along with the number of studies included in each, are summarized in Table 2.

Table 2. Key results of the meta-analyses

Outcome	Subjects	# of Studies	Odds Ratio Central Estimate (CI)	Estimated % Increase in Damp Homes
Upper respiratory tract symptoms	All	13	1.70 (1.44-2.00)	52
Cough	All	18	1.67 (1.49-1.86)	50
	Adults	6	1.52 (1.18-1.96)	--
	Children	12	1.75 (1.56-1.96)	--
Wheeze	All	22	1.50 (1.38-1.64)	44
	Adults	5	1.39 (1.04-1.85)	--
	Children	17	1.53 (1.39-1.68)	--
Current asthma	All	10	1.56 (1.30-1.86)	50
Ever-diagnosed asthma	All	8	1.37 (1.23-1.53)	33
Asthma development	All	4	1.34 (0.86-2.10)	30

Central estimates of ORs ranged from 1.34 to 1.75. Confidence intervals (95%) excluded unity for 10 of 11 analyses, and in most cases the lower bound of the CI exceeded 1.2. For wheeze and cough, the ORs for health effects in children were slightly higher than corresponding ORs for adults. The CI for asthma development was broad, with a lower bound below unity, presumably because the analyses included data from only four studies. The estimated associated percent increases in health outcomes for all subjects in damp houses ranged from 30% to 52%.

Figure 1 shows, as an example, ORs and CIs for the association of wheeze with dampness and mold in the original studies, and also from the summary estimate produced in the meta-analysis.

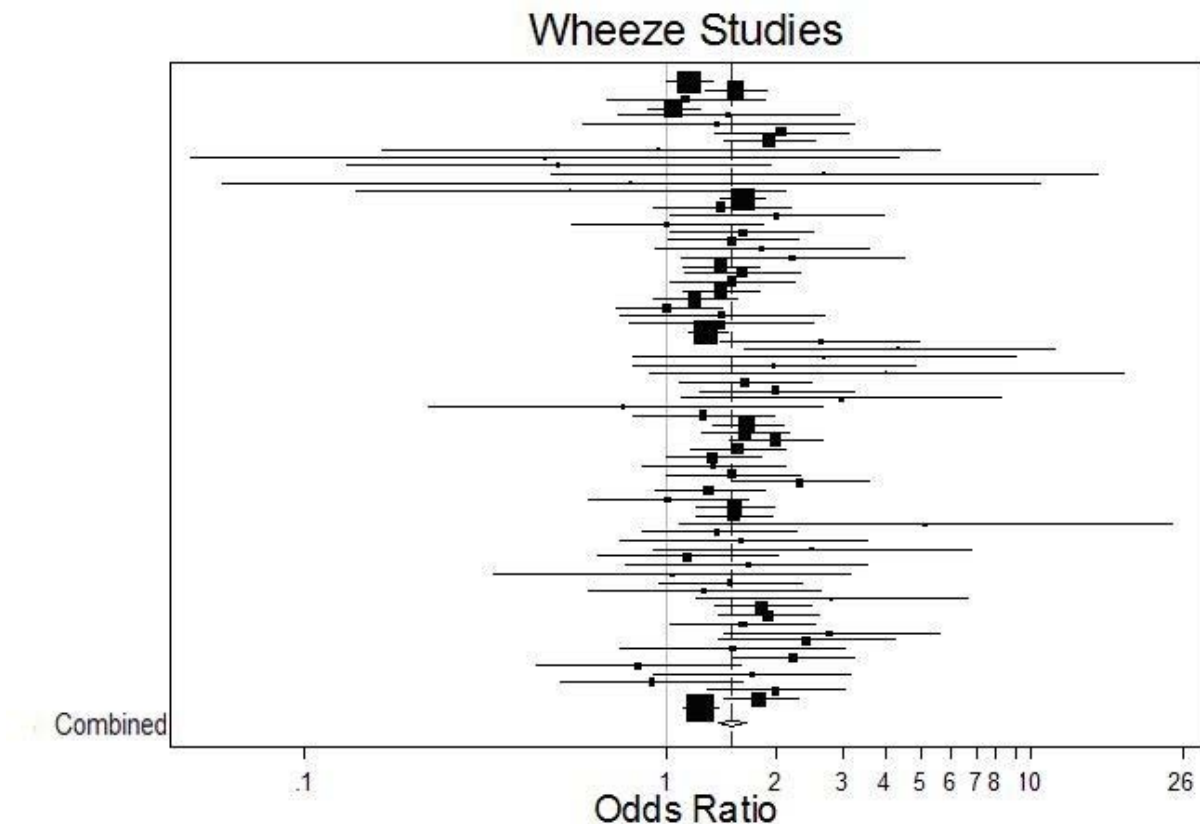


Figure 1. Odds ratios and confidence intervals for wheeze from original studies and from a meta-analysis performed using the random effects model and assuming dependent sub-studies. The width of the boxes (some so small they appear as points) is proportional to the precision (inverse of variance) of the study and the ends of the horizontal lines represent lower and upper 95% confidence limits. The left vertical line is located at an odds ratio of unity which corresponds to no increased risk of wheeze, while nearly all the reported odds ratios are greater than unity indicating an increase in risk with dampness and mold. The central estimate from the meta-analysis is indicated by the right vertical line and the left- and right-side points of the diamond (labeled “Combined”) at the bottom of the figure indicate the lower and upper 95% confidence limits from the meta-analysis.

DISCUSSION

Importance of building dampness

The meta-analyses described in this report suggest that building dampness and mold are associated with increases of 30% to 50% in a variety of health outcomes in a variety of populations. These associations are statistically significant – with 95% CIs excluding unity -- in almost all cases.

While statistical associations do not prove that dampness and mold are causally related to the health outcomes, and building dampness itself is very unlikely to directly cause adverse health effects, the consistent and relatively strong associations of dampness with adverse health effects strongly suggest causation by dampness-related exposures. Building dampness may cause the building to become contaminated with microorganisms such as mold or bacteria, which might in turn cause adverse health effects (IOM 2004). Building dampness could also cause increased emissions of some chemical pollutants from materials and surfaces (IOM 2004). Research has not yet determined the exact causal agent(s) (IOM 2004).

The increased risk associated with building dampness suggests a potentially large public health problem. Most available data indicate that at least 20% of homes have dampness problems or visible mold (IOM 2004). In addition, the adverse consequences of building dampness go beyond health effects and the related personal and economic costs. Dampness causes structural damage to buildings that is expensive to repair. Also, mold contamination resulting from building dampness often precipitates very expensive remediation efforts (Levin 2005).

While this analysis does not specifically prove causation between dampness or mold and these health effects, it strongly supports the need to prevent building dampness and mold and to take corrective actions where such conditions occur, as suggested in the IOM report (IOM 2004). Many of the preventive and corrective actions are straightforward. Examples include better moisture control in design, moisture control practices during construction, and improved ongoing preventive maintenance programs to identify and quickly remedy roof and plumbing leaks or other causes of moisture accumulation or mold growth.

Limitations in this analysis

One potential source of bias pertains to the methods used to determine whether a building had dampness or mold. Most studies have relied on the occupants to report whether dampness or mold is present in their home. It is possible that homeowners with respiratory problems would be more aware of or concerned about, and thus, more likely to report, dampness and mold than homeowners without such health problems. If true, this reporting bias would lead to overestimated ORs in the original studies and corresponding overestimated ORs from our meta-analyses. On the other hand, as homeowners within each study would report dampness or mold in a relatively unstandardized and inaccurate way, the resulting random error in assessment could result in what is called “nondifferential exposure misclassification,” leading to underestimated ORs in those studies. In the course of this review, we identified six papers that provide some information about the potential bias from self-reporting of mold and dampness. Brief summaries of the relevant information are provided below:

- To validate a questionnaire that asked occupants to self-report dampness, Andrae et al (1988) had inspectors visit 34 houses and inspect for dampness signs. In 23 of the 34 inspected houses, occupants had reported dampness. Inspectors noted visible mold in 14 out of 23 houses and signs of dampness in the remaining 9 of 23. Inspectors found dampness in only 3 of 11 houses that did not have self-reported dampness. The authors concluded “when parents claimed dampness ..., experienced health inspectors agreed.”
- Emenius et al. (2004) conducted a case-control study of wheeze that included both parental reports and inspector-confirmed signs of dampness; however, the two dampness assessments were for different time periods. Inspectors reported mold and window pane

condensation more often than parents but found any moisture or mold less often than parents. Although direct quantitative comparisons are not possible, wheeze was associated with both self-reported and inspector-reported signs of dampness.

- Nafstad et al (1998) found a substantially stronger association of bronchial obstruction with parent-reported plus inspector-confirmed dampness [OR 3.8 CI (2.0 – 7.2)] than with parent-reported but not confirmed dampness [OR 2.5 CI (1.1 – 5.5)].
- Norbäck et al. (1999) had industrial hygienists visit 62 houses and check for four signs of dampness. Previously, occupants had responded to questions about the same four signs of dampness. The authors concluded that “questions on building dampness, water damage, and mold were reliable.” Detailed results are provided in the paper.
- Verhoeff et al (1995) assessed dampness via a parent-completed questionnaire and via trained investigators in a case-control study of respiratory symptoms with 259 cases and 257 controls. Based on the data provided, in homes of respiratory cases the inspectors’ and parents’ reports were mutually consistent 78% of the time for dampness and 85% of the time for mold. In homes of control subjects, the corresponding numbers were 71% and 85%. The authors concluded there was “no indication of over reporting of dampness and mold by parents of cases relative to the parents of controls.” ORs for self-reported dampness in homes of respiratory cases were larger than corresponding ORs for inspector-observed dampness; however, ORs for self-reported mold in homes of respiratory cases were smaller than ORs for inspector-observed mold.
- In another case-control study, Williamson (1997) obtained data on self-reported dampness and mold and also had a surveyor visit homes and assess dampness and mold. If the surveyors’ responses were treated as the “gold standard,” both asthmatic and control subjects underreported dampness. The OR for the association of case status with self-reported dampness was 1.93 (1.14–3.28), while the OR for the association of case status with inspector-reported dampness was 3.03 (1.65 – 5.57).

Based on these six studies, it seems very unlikely that the observed association of respiratory health effects with dampness and mold is a consequence of over-reporting of dampness and mold by occupants with respiratory symptoms.

Reviews and meta-analyses are also subject to publication bias – the overestimation of summary estimates of association that can occur because studies with positive findings are published more often (IOM 2004, pg 20) and more quickly than studies that failed to find significant associations. Publication bias would bias the results of our meta-analyses upward; i.e., estimated ORs based only on all published studies would exceed true central estimates based on all performed studies. While there are statistical tools available that enable one to check for evidence of publication bias, it remains difficult to quantify the extent of publication bias or to make corrections in the resulting central estimates of ORs. We created and examined funnel plots² for the asymmetries indicative of publication bias; i.e., for the smaller studies most often having ORs above the central estimate, suggesting non-publication of those smaller studies with ORs below the overall central estimate. The funnel plots provided no consistent evidence of publication bias. However, in the course of reviewing papers, we identified one that specifically stated that results for the association of a respiratory effect with dampness were not presented because the association was not statistically significant – a clear example of publication bias.

² The heterogeneity of sets of observational studies makes it difficult to draw firm conclusions about publication bias based on funnel plots (Egger et al. 1998).

It is important to note that the confidence intervals associated with our central estimates of ORs reflect only the probabilistic or chance uncertainties. The full uncertainties in the magnitudes of increased health risks are likely to be larger because they would also include potential uncontrolled confounding and bias such as noted above.

Asthma development -- comparison to findings of IOM

The IOM Committee found limited or suggestive evidence of an association between building dampness and asthma development, and inadequate or insufficient evidence to determine whether an association exists between mold and asthma development. These statements are consistent with the results of our meta-analysis. We calculated an OR of 1.34 for asthma development if the home had dampness or mold; however, the 95% CI (0.86-2.10) included unity. Also, our meta-analysis for asthma development was based on only four studies and the definitions for asthma development used in these studies were variable.

CONCLUSIONS

This meta analysis suggests that building dampness and mold are associated with increases of 30% to 50% in a variety of respiratory and asthma-related health outcomes, and the associations are statistically significant in nearly all cases. These results support a recommendation to prevent building dampness and mold problems in buildings, and to take corrective actions where such problems occur.

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Appendix 1. Description of studies included in the meta-analyses.

Table A1.1 Studies with upper respiratory tract symptoms

Subjects	Author	Year	Risk Factor	Symptomx
Adults	Engvall	2001b	Condensation	nasal
			mold odor	
			water leakage	
	Koskinen	1999b	surveyor-assessed moisture	rhinitis
	Pirhonen	1996	dampness or mold	allergic rhinitis
				rhinitis
Children	Bornehag	2005	water leakage	rhinitis
			floor moisture	
			visible dampness	
			condensation	
	Brunekreef	1989	damp ever	hay fever
			mold ever	
	Jaakkola	1993	any dampness indicator ever	nasal congestion
				nasal excretion
			mold odor last year	nasal congestion
				nasal excretion
			visible mold last year	nasal congestion
				nasal excretion
			moisture past year	nasal congestion
				nasal excretion
			water damage past yr	nasal congestion
				nasal excretion
	Jedrychowski	1998	molds or dampness	hay fever
	Li	1997	Dampness	allergic rhinitis
			Mold	
			water damage	
			stuffy odor	
			Flooding	
			any dampness or mold indicator	
	Koskinen	1999b	surveyor-assessed moisture	rhinitis
				sinusitis
	Simoni	2005	mold or dampness in first year of life	nasal symptoms apart from colds
			mold or dampness current but not in 1st year	
			mold or dampness 1st year and current	
	Stark	2005	water damage or mold or mildew	allergic rhinitis
	Waegemaekers	1989	Dampness	runny nose
	Yang	1997b	mold or mildew or standing water , or water damage, or water leaks	allergic rhinitis

Table A1.2 Studies with cough as an outcome

Subjects	Author	Year	Risk	Health outcome
adults	Engvall	2001b	condensation	cough
			Mold odor	
			water leakage	
	Gunnbjörnsdottir	2003	water damage	long-term cough
				nocturnal cough
			Mold	long-term cough
				nocturnal cough
	Gunnbjörnsdottir	2003	water damage or mold	long-term cough
				nocturnal cough
	Gunnbjörnsdottir	2006	water damage	new nocturnal cough in last 12 months
	Haverinen	2001	moisture problem based on inspector	cough without phlegm
				cough with phlegm
				nocturnal cough
	Koskinen	1999b	surveyor assessed moisture	cough w/o phlegm
				night cough
				cough w/ phlegm
			owner reported mold	cough w/o phlegm
				night cough
	Pirhonen	1996	Mold or damp	cough w/phlegm
	Skorge	2005	Mold before last year	cough
				cough with phlegm
			Mold last year and earlier	chronic cough
				cough with phlegm
			water damage before last year	chronic cough
			water damage last year and earlier	cough with phlegm
children	Bornehag	2005	water leakage	cough at night
			Floor moisture	
			visible dampness	
			condensation	
	Brunekreef	1989	damp ever	cough
			Mold ever	
	Brunekreef	1992b	damp stains	cough on most days
			Mold	
	Cuijpers	1995	Mold always vs. never	chronic cough
			Mold often vs. never	
			Mold sometimes vs. never	

Subjects	Author	Year	Risk	Health outcome
infants w/ asthmatic sibling	Jaakkola	1993	any dampness indicator ever	persistent cough
			Mold odor last year	
			visible mold last year	
			moisture past year	
			water damage past yr	
	Jedrychowski	1998	Mold or damp	chronic cough
	Koskinen	1999b	moisture	cough w/ phlegm
				cough w/o phlegm
				night cough
	Mommers	2005	Mold or dampness short period vs never	coughing
			Mold or dampness long period vs never	
			Mold or dampness always vs never	
	Simoni	2005	Mold or dampness in first year of life	persistent cough and/or phlegm (two age groups)
			Mold or dampness current but not in 1st year	
			Mold or dampness 1st year and current	
	Waegemaekers	1989	dampness	day or night cough
	Yang	1997	dampness, mold, or flooding	morning cough
	Yang	1997b	mold or mildew or standing water , or water damage, or water leaks	cough 3 months of year apart from colds
	Gent	2002	water leaks	cough 3 months of year apart from colds
				cough

Table A1.3 Studies with wheeze as an outcome.

Subjects	Author	Year	Risk	Outcome
adults	Gunnbjörnsdottir	2003	water damage	wheeze or whistling in chest
	Gunnbjörnsdottir	2003	Mold	wheeze or whistling in chest
	Gunnbjörnsdottir	2003	water damage or mold	wheeze or whistling in chest
	Gunnbjörnsdottir	2006	water damage	new whistling or wheezing in chest in last 12 months
	Haverinen	2001	moisture problem based on inspector	wheeze
	Norbäck	1999	>1 signs of dampness	wheeze
			damp floor	
			visible mold on indoor surfaces	
			moldy odor	
	Skorge	2005	water damage or flood	wheeze in last 12 months
			Mold before last year	
			Mold last year and earlier	
			water damage before last year	
			water damage last year and earlier	
children	Bornehag	2005	water leakage	wheeze
			Floor moisture	
			visible dampness	
			condensation	
	Brunekreef	1989	damp ever	wheeze
		1989	molds ever	wheeze
	Cuijpers	1995	Mold always vs. never	wheeze
			Mold often vs. never	
			Mold sometimes v. never	
	Emenius	2004	dampness, any self-reported (case-control)	recurrent wheeze
			Mold odor self -eported (case-control)	
			Mold at shower bath tile joints via inspector (case-control)	
			dampness, any sign via inspector (case-control)	
			dampness self-reported or noted by inspector (case-control)	
			dampness both self-reported and by inspector (case-control)	
			condensation on windows self-reported and via inspection (case-control)	
			damage by dampness, self-reported (cohort)	
			Mold odor self-reported (cohort)	
			visible mold last year, self-reported (cohort)	
			any sign of dampness, self reported (cohort)	
	Jaakkola	1993	any dampness indicator ever	persistent wheeze
			Mold odor last year	
			visible mold last year	
			moisture past year	
	Jedrychowski	1998	water damage past yr	wheeze
			Mold or damp	

Subjects	Author	Year	Risk	Outcome
	Maier	1997	water damage	wheeze in last 12 months
			any dampness except water damage	
	Mommers	2005	Mold or dampness short period vs never	wheeze
			Mold or dampness long period vs never	
			Mold or dampness always vs never	
	Ronmark	2002	dampness	wheeze
	Simoni	2005	Mold or dampness in first year of life	current wheeze (two age groups)
			Mold or dampness current but not in 1st year	
			Mold or dampness 1st year and current	
	Slezak	1998	Mold or damp	wheeze in past 12 months
	Venn	2003	visible mold	wheeze in last year
			meas living room damp low vs very low	
			meas living room damp moderate vs very low	
			meas living room damp high vs very low	
			meas kitchen damp low vs very low	
			meas kitchen damp moderate vs very low	
			meas kitchen damp high vs very low	
			meas bedroom damp low vs very low	
			meas bedroom damp medium vs very low	
	Waegemaekers	1989	dampness	wheeze
	Yang	1997	dampness, mold, or flooding	wheeze apart from colds on most days or wheeze after exercise
	Yang	1997b	Mold or mildew or standing water , or water damage, or water leaks	wheeze apart from colds on most days or wheeze after exercise
infants w/ asthmatic sibling	Gent	2002	water leaks	wheeze

Table A1.4 Studies with asthma diagnosis as an outcome.

Subjects	Author	Year	Risk	Outcome description*
adults	Pirhonen	1996	dampness or mold	Dr. dx asthma
	Skorge	2005	mold before last year	Dr. dx asthma
			mold last year and earlier	
			water damage before last year	
			water damage last year and earlier	
children	Bornehag	2005	water leakage	Dr. dx. asthma
			floor moisture	
			visible dampness	
			condensation	
	Jedrychowski	1998	mold or damp	Dr. dx. asthma
	Lee	2003	water damage	Dr. dx. asthma
			visible mold	
	Maier	1997	water damage	Dr. dx. asthma
			any dampness except water damage	
children & adults	Slezak	1998	damp or mold	Dr. or nurse dx asthma
	Yang	1998	mold or mildew or standing water , or water damage, or water leaks	Dr. dx. asthma
	Williamson	1997	damp	Dr. dx asthma
			damp or condensation current home	
			damp previous home	
			mold	
			severe damp	
			significant mold	

Abbreviations: sx = symptom; dx = diagnosis; Dr. = doctor

Table A1.5 Studies with current asthma as an outcome.

Subjects	Author	Year	Risk	Outcome description*
adults	Norbäck	1999	>1 dampness factor	current asthma defined as combination of bronchial hyper-responsiveness and at least one asthma sx in last year
			damp floor	
			moldy odor	
			visible mold	
			water damage or flood	
children	Brunekreef	1989	damp ever	Dr. dx asthma in past year
			mold	
	Dales	1999	mold or mildew in last 12 months	Dr. dx. asthma and current asthma or regular asthma medications
	Dekker	1991	dampness or visible mold or water damage	Dr. dx asthma + current sx
	Jaakkola	1993	any damp indicator ever	current Dr. dx asthma
			moisture past yr	
			mold odor past yr	
			visible mold past yr	
	Li	1997	dampness	current Dr. dx asthma
			mold	
			water damage	
			stuffy odor	
			flooding	
	Simoni	2005	any dampness or mold indicator	current Dr. dx asthma (two age groups)
			mold or dampness current but not in 1st year	
			mold or dampness 1st year and current	
	Yang	1997	damp home	current Dr. diagnosed asthma
Adults and children	Williamson	1997	self-reported serious dampness and condensation	doctor diagnosed asthma and attendance of asthma clinic in 4 month period prior to study
			self-reported previous home damp	
			inspector-determined any dampness	
			inspector-determined severe dampness	
			inspector-determined any mold	
			inspector-determined significant mold	

Abbreviations: sx = symptom; dx = diagnosis; Dr. = doctor

Table A1.6 , Studies with asthma development as an outcome.

Subjects	Author	Year	Risk	Outcome description*
adults	Jaakkola	2002	damp stains or paint peeling	new Dr. dx asthma in past year
			visible mold or odor	
			water damage	
	Jaakkola	2005	any dampness or mold indicator	new doctor-diagnosed asthma between baseline study and follow-up study after six years
			mold odor	
			visible mold	
			moisture on surfaces	
			water damage	
	Simoni	2005	mold or dampness in first year of life	asthma diagnosis in last 12 months plus sx (two age groups)
	Thorn	2001	Damp	Dr. dx asthma since age > 16
			damp or visible mold	
			visible mold	
men	Yang	1998	damp or mold or water damage	first-time Dr. dx asthma
	Thorn	2001	Damp	Dr. dx asthma since age > 16
			damp or visible mold	
			visible mold	
	Thorn	2001	Damp	Dr. dx asthma since age > 16
			damp or visible mold	
			Damp	

Abbreviations: dx = diagnosis; Dr. = doctor